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SIGNAL ANALYSIS USING THE ACOUSTO-OPTIC SPECTRUM ANALYZER.(U)
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TECHNICAL NOTE NO. 80-2

SIGNAL ANALYSIS USING THE ACOUSTO-OPTIC SPECTRUM ANALYZER

by

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Radar ESM Section
Defence Electronics Division

PROJECT NO.
31B00

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OTTAWA

ABSTRACT

This paper examines the instantaneous, Fourier power spectrum for different types of input signals such as CW, pulse modulated CW and linear FM signals using the acousto-optic spectrum analyzer. The effect on the time-integrated output intensity distribution due to the truncation of the propagating acoustic signal by the finite aperture width of the Bragg cell is also analyzed. Some experimental results on pulse-modulated CW and linear FM signals are presented, and then compared with theory.

RÉSUMÉ

Ce rapport examine la distribution instantanée Fourier du spectre de puissance pour différents types de signaux d'entrés tel que CW, CW avec modulation par pulsations, et modulation F.M. linéaire, utilisant l'analyseur de spectre "Acousto-optic". L'effet sur l'intégration à la sortie de la distribution d'intensité causée principalement par la coupure du signal acoustic par la largeur limitée de l'ouverture de la cellule Bragg est aussi analysé. Quelques résultats expérimentaux sur des signaux à modulation par pulsations et modulation FM linéaire sont présentés et comparés avec la théorie.

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The author wishes to express his thanks to G. Rumbold for his stimulating discussions throughout the work. I would also like to thank L. Rowlandson for reviewing the paper with many valuable suggestions.

INTRODUCTION

Spectrum analysis using acousto-optic diffraction is well known for its inherent capability of wideband spectrum analysis on a real-time basis with many simultaneous signals present. The diffraction of a plane wave, monochromatic, light beam by a single acoustic signal is well understood and analyzed by W.R. Klein and B.D. Cook (1967) and R. Adler (1967). A coupled mode formulation is developed by Hecht (1977) for the analysis of acousto-optic diffraction with multiple acoustic waves at different carrier frequencies. A review covering the real-time optical Fourier spectrum analysis on topics such as weighting functions, frequency resolution and side lobe level is also given by Hecht (1977). For small signal analysis, the acoustic signal can be modelled as a travelling wave phase grating as presented by M. King (1967) and W.T. Maloney (1969). The emerging light phase front is diffracted in passing through the modulator which produces an additional quadrature component of the optical carrier amplitude modulated by the acoustic signal.

In this paper the instantaneous, light intensity distribution in the frequency plane is computed for different types of input signals using the travelling wave phase-grating model in the Bragg regime. Time-integrated output intensity distributions are also plotted for pulse-modulated CW signals with different pulse-widths and a linear FM. They are then compared with experimental values.

2.0 THEORETICAL FORMULATION

The schematic diagram of the acousto-optic spectrum analyzer is shown in Figure 1, with a collimated light wave impinging on the Bragg cell at the Bragg angle θ_B. Assuming the Fourier transform lens is ideal, the diffracted field distribution in the frequency plane in one dimension is approximately given by:

$$U_1(y_1,t) = AE_0 \exp\left[-j2\pi\nu(t - \frac{2F}{c}\right] \frac{P}{\lambda F} .$$

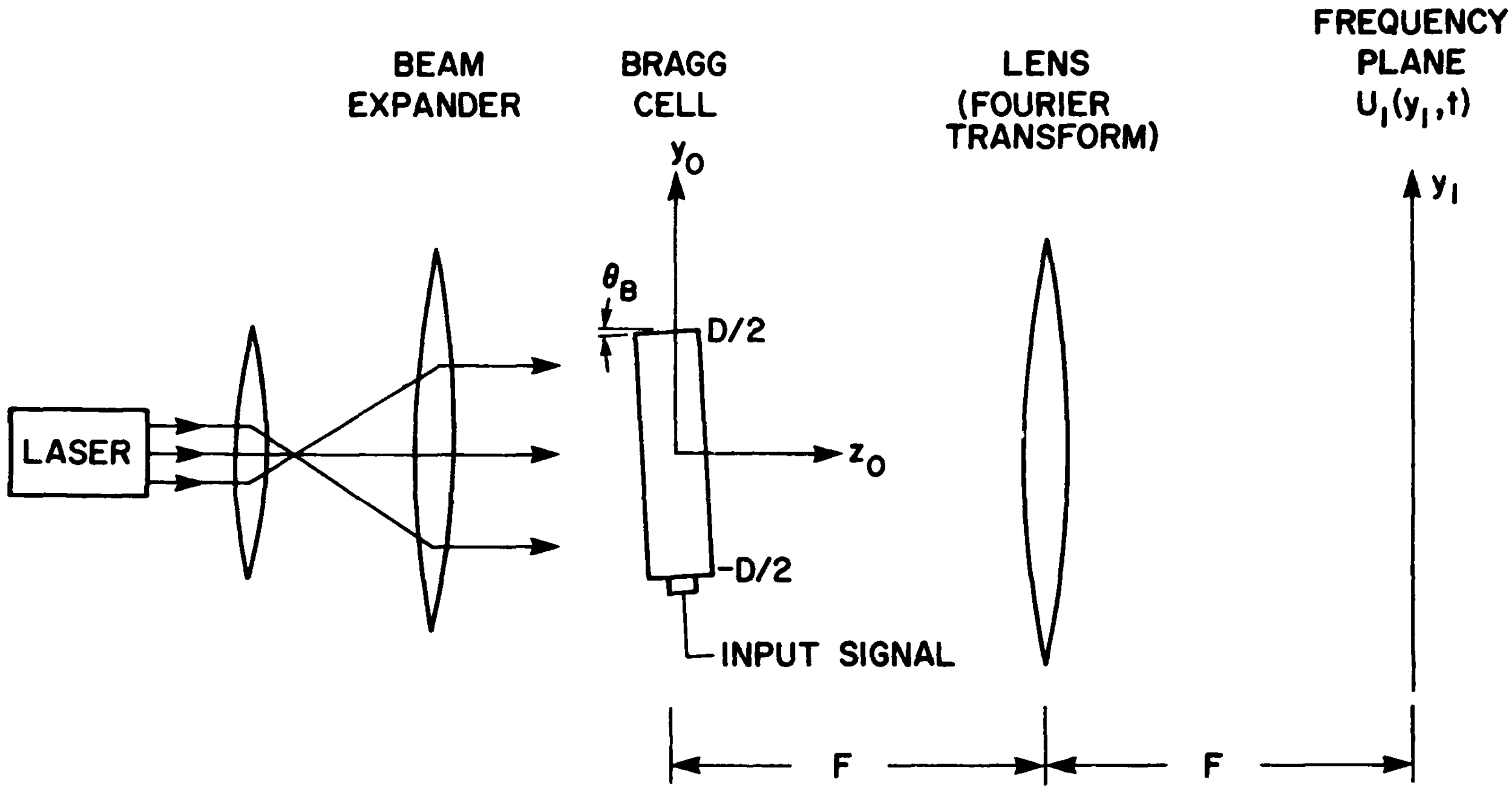

Figure 1 - SCHEMATIC DIAGRAM OF ACOUSTO-OPTIC SPECTRUM ANALYZER

$$\int_{-D/2}^{D/2} g(y_0 \cos \theta_B - v_s t)\, w(y_0) \exp \left[-j \frac{2\pi}{\lambda F} (y_1\ y_0)\right] dy_0 \tag{1}$$

where:

$$g(y_0 \cos \theta_B - v_s t) \approx g(y_0 - v_s t), \text{ for } \theta_B << 1$$

is the normalized travelling acoustic signal wave

P = height of Bragg cell aperture

A = a collection of constants including the elasto optic diffraction efficiency

v_s = acoustic wave velocity

λ = c/ν is the optical wavelength

The amplitude weighting window function $[w(y_0)]$ which includes the truncated Gaussian beam profile and the acoustic attenuation is given by:

$$w(y_0) = \exp \left[-\alpha(f)\ \tau \left(\frac{y_0}{D} + \tfrac{1}{2}\right) - \left(2T \frac{y_0}{D}\right)^2\right] \tag{2}$$

Where T specifies the truncated Gaussian beam profile, α is the acoustic loss coefficient in nepers/sec and τ is the acoustic transit time across the aperture.

Equation (1) can be rewritten as a convolution of the spatial Fourier transform of the input signal and the Fourier transform of the amplitude weighting function as follows:

$$U_1\ (y_1,t) = AE_0 \exp \left[-j2\pi\nu\left(t - \frac{2F}{c}\right)\right] \frac{P}{\lambda F} \cdot$$

$$\int_{-\infty}^{\infty} G(f/v_s)\, W(\frac{y_1}{\lambda F} - f/v_s)\, d(f/v_s) \tag{3}$$

where

$$G(f/v_s) = \int_{-D/2}^{D/2} g(y_0 - v_s t) \exp\,[-j2\pi f\, y_0/v_s]\, dy_0 \tag{4}$$

$$W(\frac{y_1}{\lambda F} - f/v_s) = \int_{-D/2}^{D/2} w(y_0) \exp\,[-j2\pi y_0\, (\frac{y_1}{\lambda F} - f/v_s)]\, dy_0 \tag{5}$$

2.1 CW and Pulse-modulated CW Carriers

Both types of signals are characterized by a constant carrier and are expressed by

$$g(y_0 - v_s t) = \mathrm{Re}\left\{A(y_0 - v_s t) \exp\,[j2\pi\, f/v_s\, (y_0 - v_s t)]\right\}$$

where $A(y_0 - v_s t)$ is the amplitude function of the signal

2.2 Linear FM

A linear FM can be expressed by

$$g(y_0 - v_s t) = \mathrm{Re}\left\{[A(y_0 - v_s t)] \exp\left\{j2\pi[f/v_s\, (y_0 - v_s t) + \frac{k}{2}\, \frac{1}{v_s^2}\, (y_0 - v_s t)^2]\right\}\right\}$$

where fo is the centre frequency and k is the rate of change of frequency in (HZ/sec).

3.0 EXPERIMENTAL ARRANGEMENT

The schematic arrangement of the experimental acousto-optic spectrum analyzer is shown in Figure 1. The optical source is the Spectra Physics Model 124B helium neon laser which delivers 15 mw of coherent optical power at 0.6328 nm. The laser beam is expanded in one dimension by the beam expander to a width of 20.5 mm with a Gaussian intensity profile truncated at $1/e^2$ points. The bulk Bragg cell used is the FJW D-150 Acousto-optic deflector with the Zenith phased array transducer giving a bandwidth of about 100 MHZ at a centre frequency of 150 MHZ. The aperture dimensions used in the experimental measurements are 2 mm by 20.5 mm with a corresponding transit time of 5 μsec. The acoustic loss coefficient is measured to be 0.5 nepers/5 μsec at the centre-frequency. A thin circular Achromat lens of diameter 50.8 mm with a focal length of 0.4 m is used to Fourier transform the weighted signal as it forms the far-field intensity distribution in its back focal plane. The lens was tested and found to produce negligible phase error for low spatial frequencies. The output intensity distribution is detected and integrated on the Fairchild CCD 110/110F linear image sensor with 256 elements. The cell size is 13 μm by 17 μm on 13 μm centers with a channel stop width of 5 μm. The information stored in the elements are clocked out serially by CCD shift registers and displayed on an oscilloscope.

4.0 COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL RESULTS FOR PULSE MODULATED CW SIGNALS

Using eq. (1), the envelopes of the instantaneous power spectra for a 5 μsec pulse modulated CW at 150 MHZ are plotted in Figures 2 and 3. They are plotted at different instants of time as the pulse propagates across the Bragg cell. The acoustic signal is attenuated and illuminated by different portions of the Gaussian profile on its course through the aperture. The effect of the amplitude weighting function is to broaden the main lobe, suppressing the side-lobe levels and filling up the nulls. Shown in Figure 2 are the two plots of the instantaneous power spectra; one with the signal completely coincident with the aperture and the other one with a quarter of the pulse interacting. As can be seen from the graph, the truncation of the signal by the finite aperture causes the frequency components to spread out with a corresponding drop in power. The instantaneous spectrum at another instant of time with half of the pulse interacting is shown in Figure 3. A listing of the computer program is given in Appendix A.

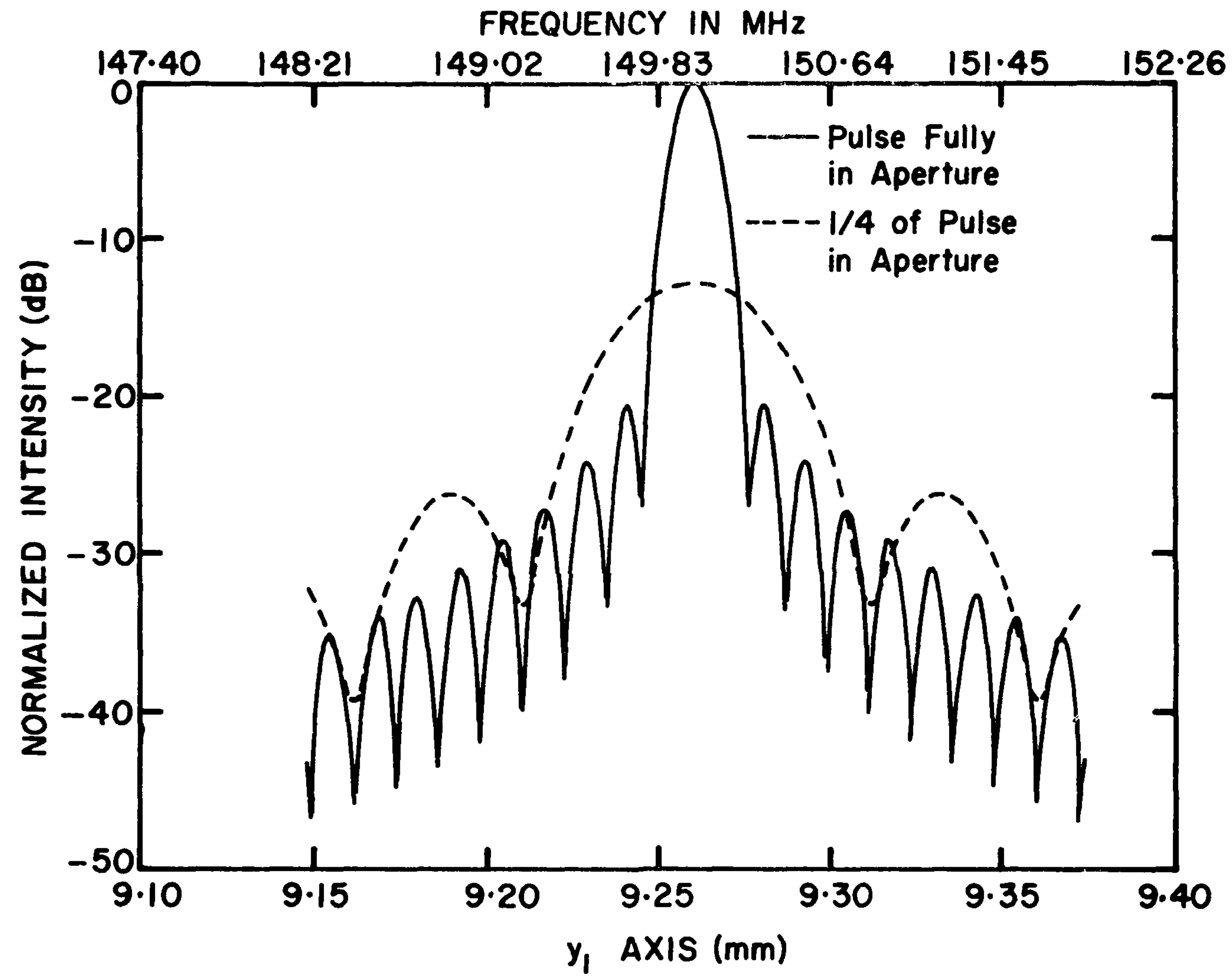

Figure 2 - LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE FOR A 5 μSEC PULSE MODULATED CW AT TWO DIFFERENT INSTANTS OF TIME (α = 0.5 NEPERS/5 μSEC, T = 1, AND D = 20.5 mm, CW = 150 MHZ)

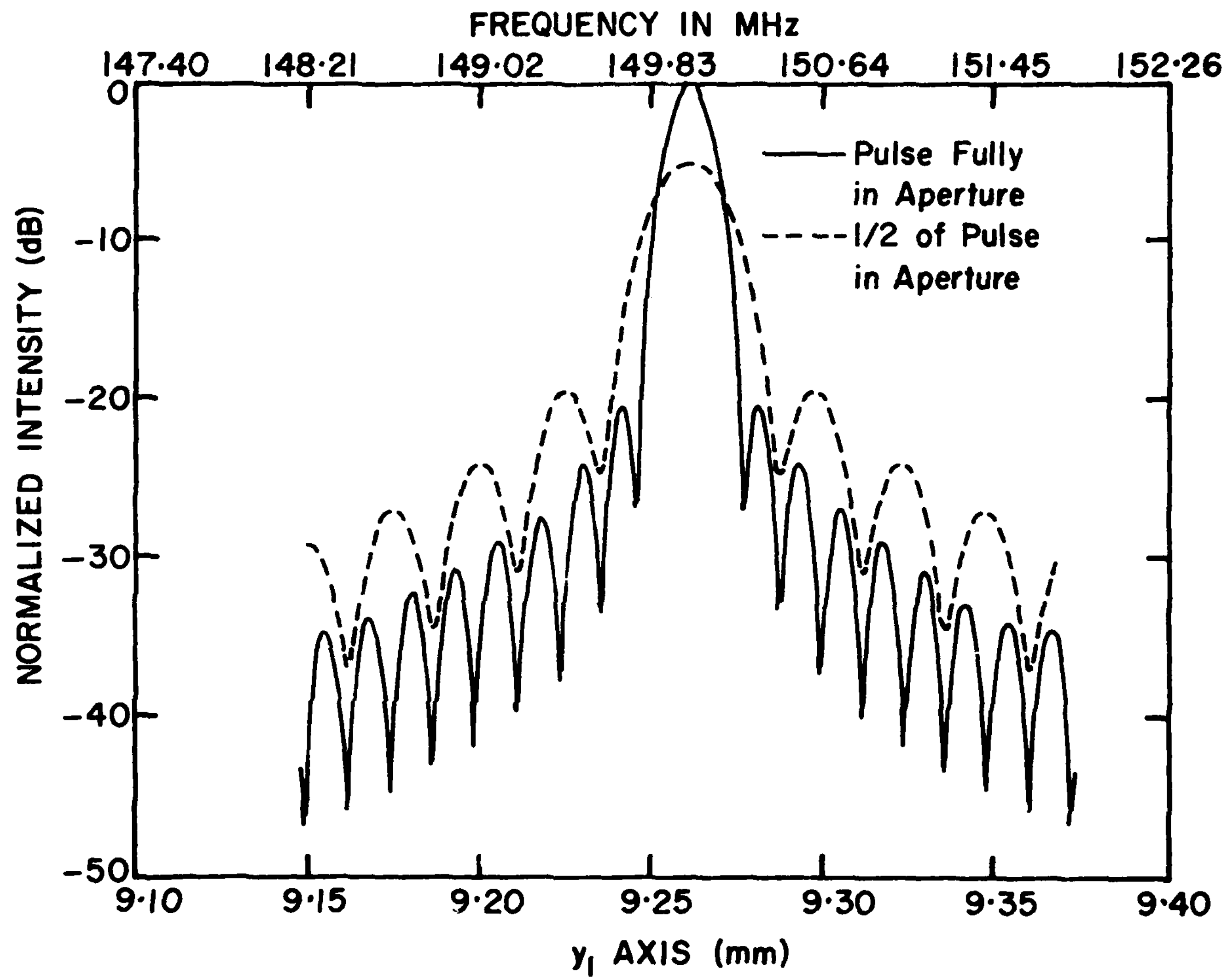

Figure 3 - LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE FOR A 5 μSEC PULSE MODULATED CW AT TWO DIFFERENT INSTANTS OF TIME

Summing up all the spectra at different instants of time, an integrated power spectrum is obtained and shown in Figure 4. The total integration time is 10 μsec which is the time interval for the pulse to transit the aperture. Figure 4 also shows the spectrum of a CW signal integrated for the same interval of time, or equivalently, it is the spectrum of a stationary 5 μsec-pulse filling up the aperture and time integrated for 10 μsec. By comparing the two plots, the effect due to the truncation of the signal by the finite aperture is to broaden the main lobe and to smooth out the side lobes. The two output waveforms are also measured experimentally and shown in Figures 5(a) and 5(b). Identical photo-cells are used in recording the two waveforms in order to minimize the effect of cell response variations. As can be seen from the figures, there is a definite spread in the main lobe due to the truncating effect. No attempt is made here to compare the theoretical and experimental results in detail because the width of the power spectrum is comparable to the size of a photo-cell and the cell to cell boundary structure introduces distortion.

Theoretical results are plotted in Figures 6 and 7 for a 1 μsec and 2 μsec pulse modulated carriers along with the corresponding experimental measurements shown in Figures 8(a) and 8(b). For these two cases, the main lobe covers a number of cells and the error introduced by the structure of the cell boundary becomes less important. The light intensity distribution is graphically integrated with a cell width of 13 μm and the results are tabulated in Table I along with the experimental values. Some of the possible sources of error in the measurement system are as follows:

a) The lenses used in the beam expander and the Fourier transform are not ideal.

b) There is error introduced by representing the beam profile with an ideal truncated Gaussian distribution.

c) There is error due to the cell-to-cell boundary structure and the photo response non-uniformity of the cells.

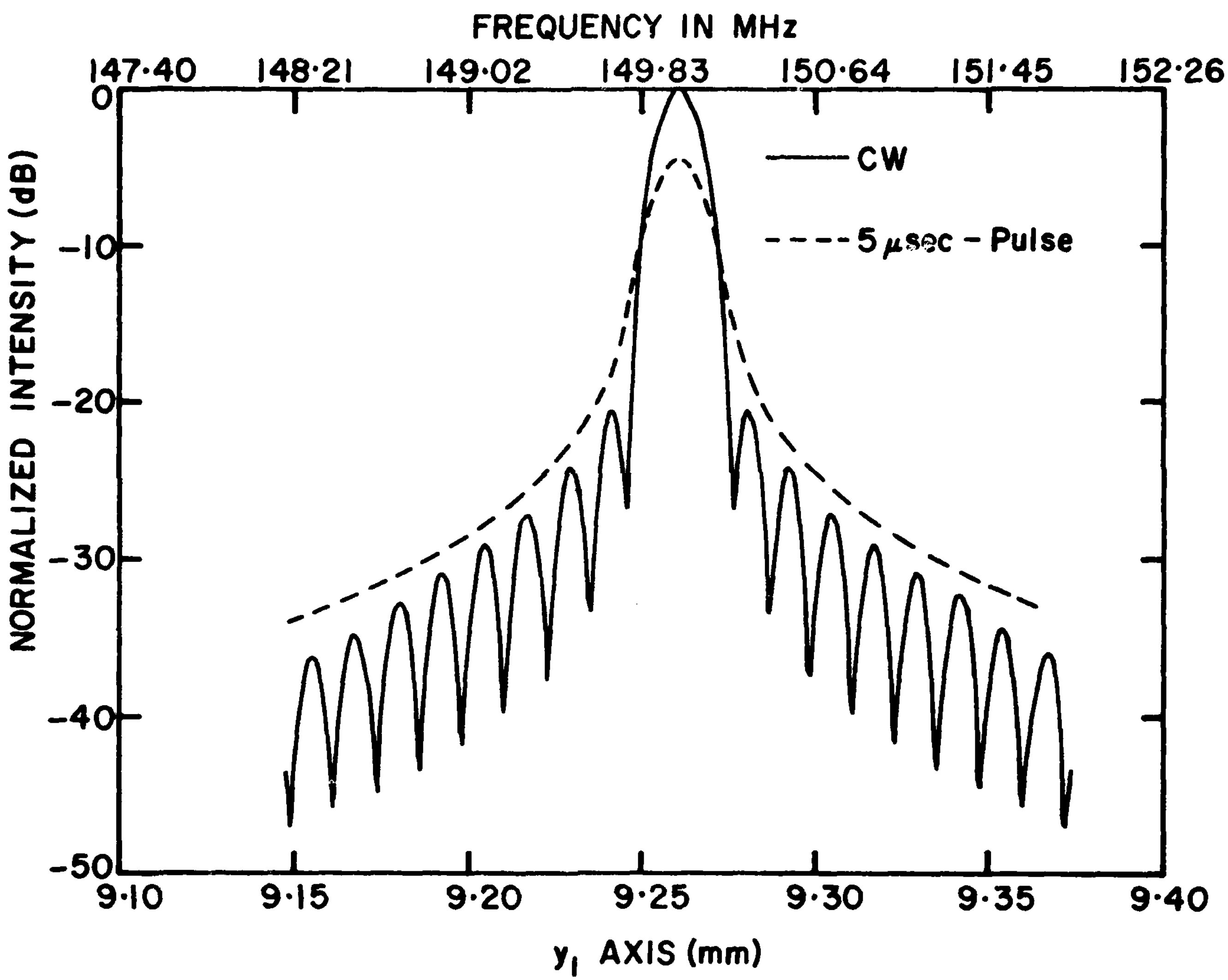

Figure 4 - INTEGRATED LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE FOR BOTH CW AND A 5 μSEC PULSE MODULATED CW. (INTEGRATION TIME = 10 μSEC, α = 0.5 NEPERS/5 μSEC, T = 1, CW = 150 MHZ AND D = 20.5 mm)

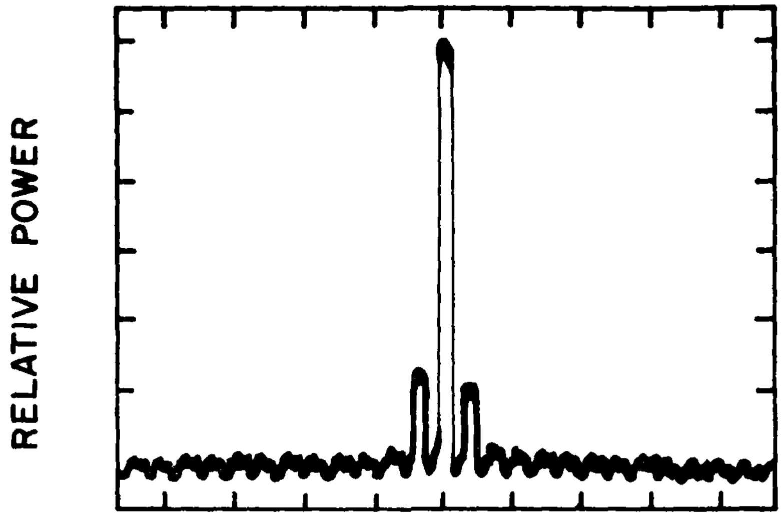

Figure 5(a) - CW

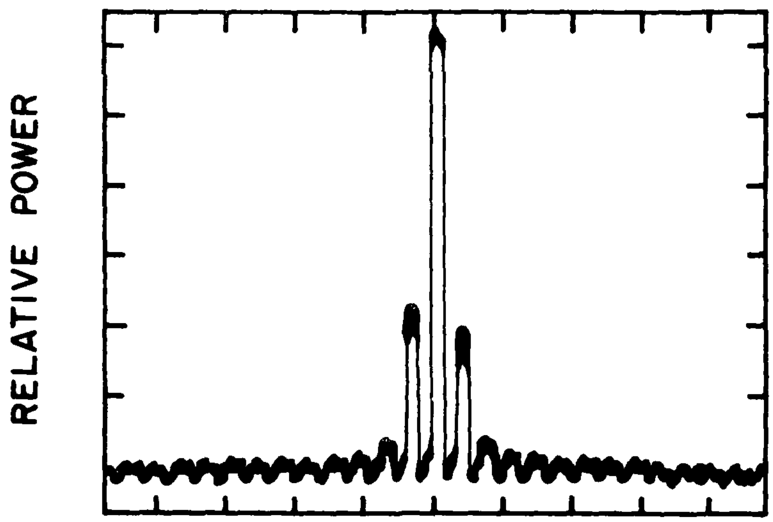

Figure 5 (b) - 5 μ SEC - PULSE

Figure 5 - INTEGRATED LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE DETECTED BY PHOTO DETECTOR ARRAY (CELL TO CELL CENTER SPACING = 13 μm, INTEGRATION TIME = 50 μSEC)

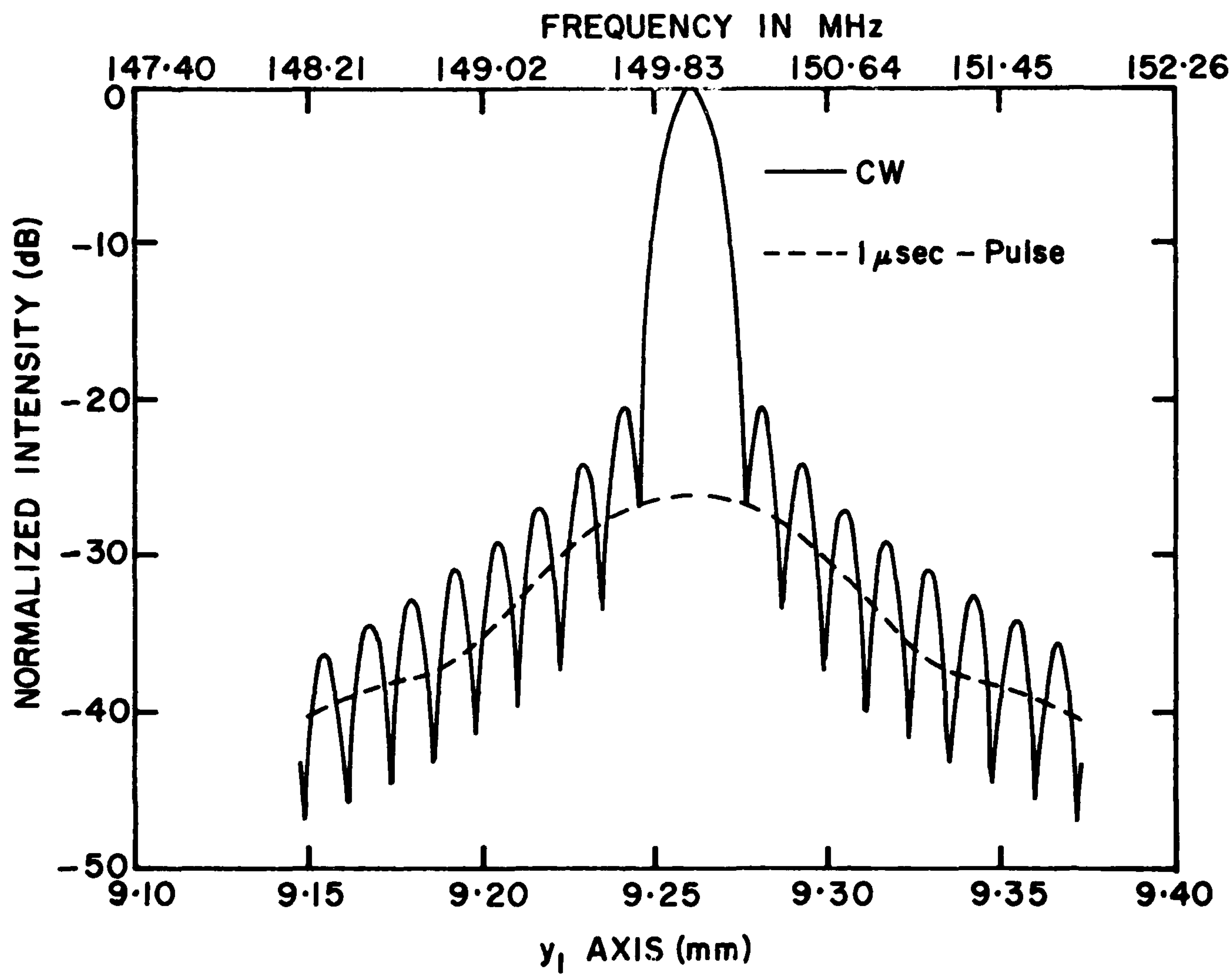

Figure 6 - INTEGRATED LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE FOR BOTH CW AND A 1 μSEC PULSE MODULATED CW. (INTEGRATION TIME = 6 μSEC, CW = 150 MHZ, α = 0.5 NEPERS/5 μSEC, T = 1 AND D = 20.5 mm)

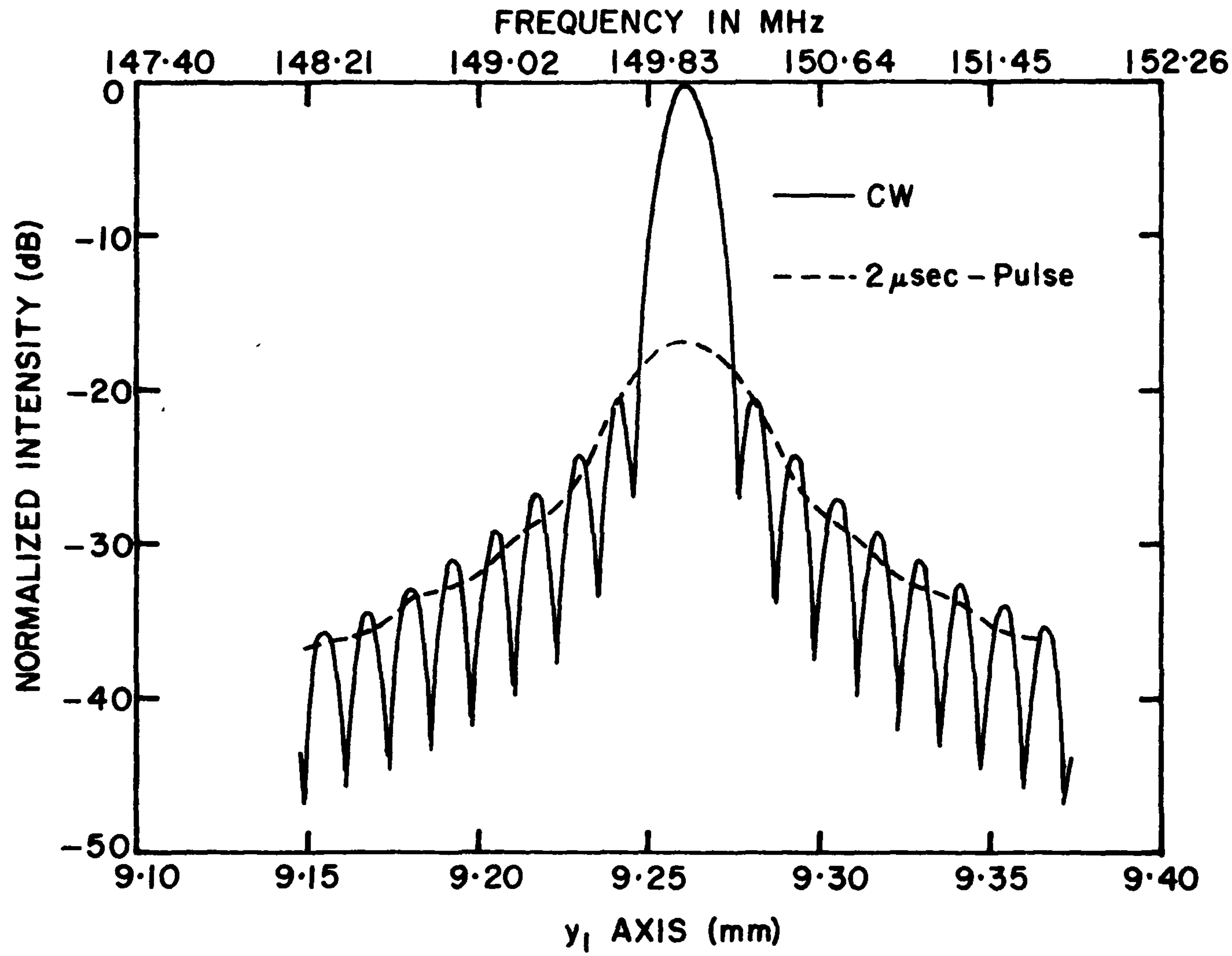

Figure 7 - INTEGRATED LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE FOR BOTH CW AND A 2 μSEC PULSE MODULATED CW. (INTEGRATION TIME = 7 μSEC, CW = 150 MHZ)

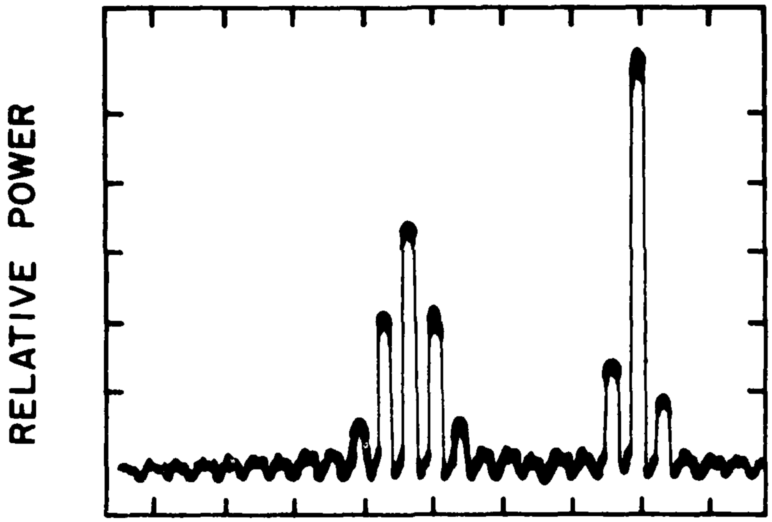

Figure 8 (a) - CW AND 2 μSEC PULSE MODULATED CW

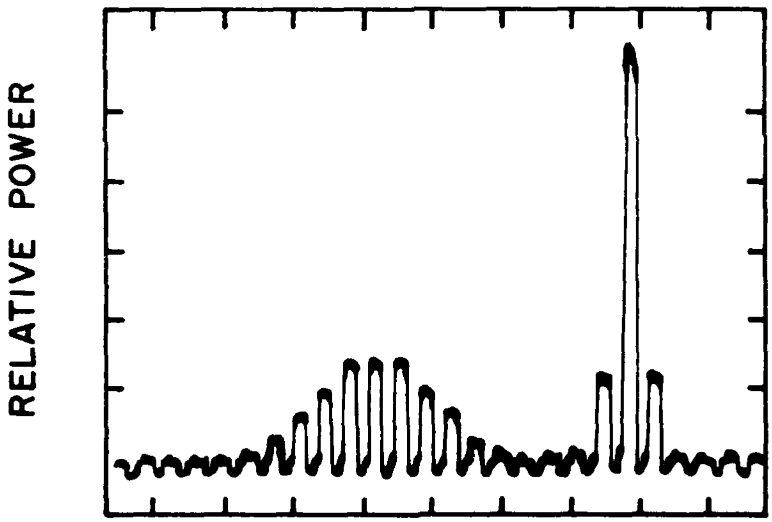

Figure 8 (b) - CW AND 1 μSEC PULSE MODULATED CW

Figure 8 - INTEGRATED LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE DETECTED BY PHOTO DETECTOR ARRAY (CELL TO CELL CENTRE SPACING = 13 μm, INTEGRATION TIME = 50 μSEC)

TABLE I

COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL INTEGRATED INTENSITY DISTRIBUTION FOR A 1 μSEC AND 2 μSEC PULSE MODULATED CW SIGNAL

PULSE-WIDTH IN μSEC	1-μSEC CW = 150 MHZ		2-μSEC CW = 150 MHZ	
	Theoretical Intensity	Experimental Intensity	Theoretical Intensity	Experimental Intensity
CENTRE CELL (Normalized to Unity	1	1	1	1
1st Cell from Centre	0.87	0.875	0.70	0.61
2nd	0.64	0.60	0.21	0.15
3rd	0.36	0.4		
4th	0.17	0.13		

The experimental results shown in Figures 8(a) and 8(b) agree reasonably well with the theoretical calculations if the sources of error are taken into account.

5.0 COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL RESULTS FOR A 5 μSEC PULSE MODULATED LINEAR FM SIGNAL

Using eqs. (1) and (7), the instantaneous power spectra of a linear FM signal are plotted in Figures 9 and 10 for different instances of time. The duration of the signal is 5 μsec with a centre frequency of 150 MHz and a frequency excursion of 2 MHz. The theoretical time-integrated power spectrum is plotted in Figure 11 and the power spectrum of the same signal, but stationary in the aperture and time-integrated for the same

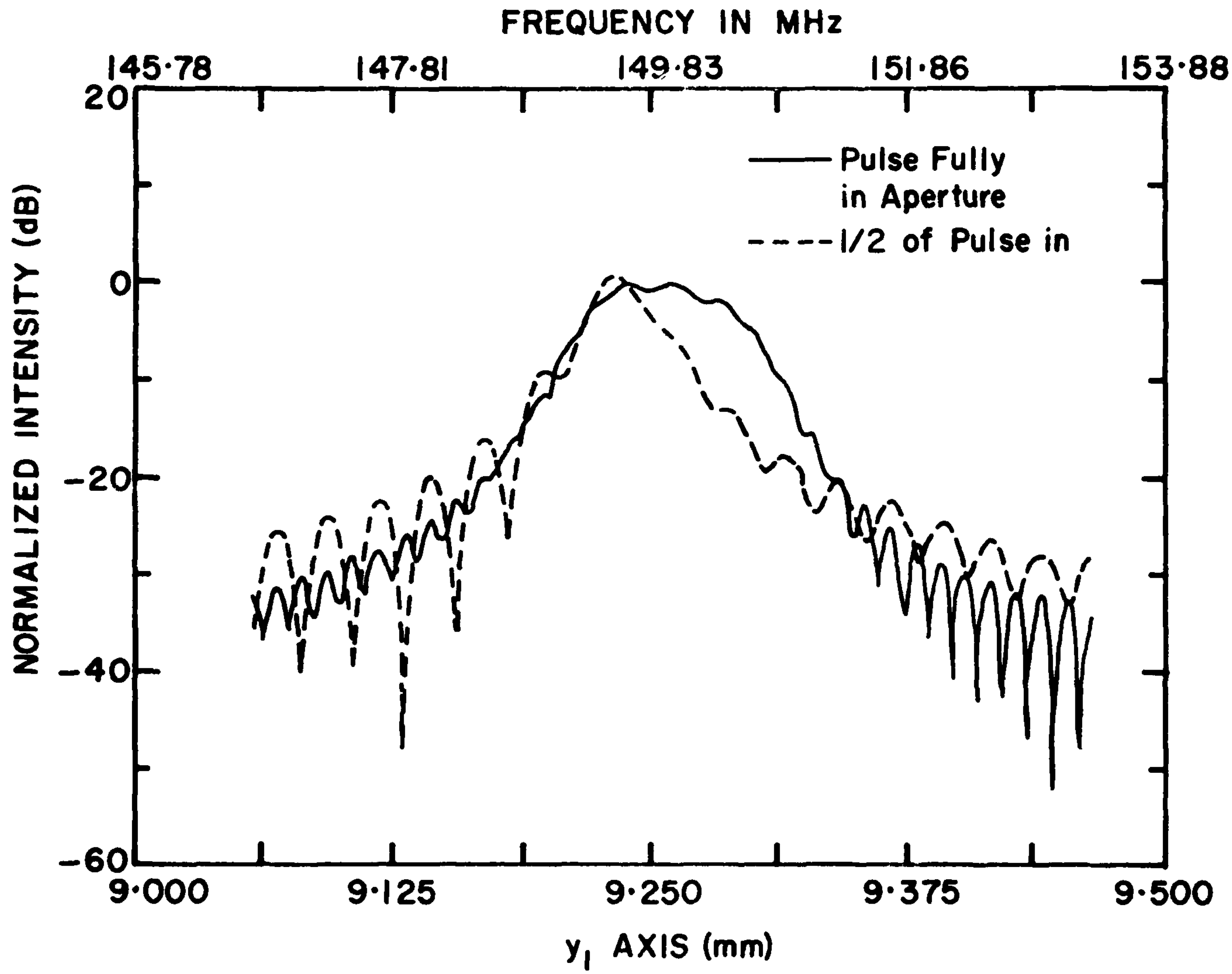

Figure 9 - LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE FOR A 5 μSEC PULSE MODULATED LINEAR FM AT TWO DIFFERENT INSTANTS OF TIME (f_o = 150 MHZ, Δ_f = 2 MHZ)

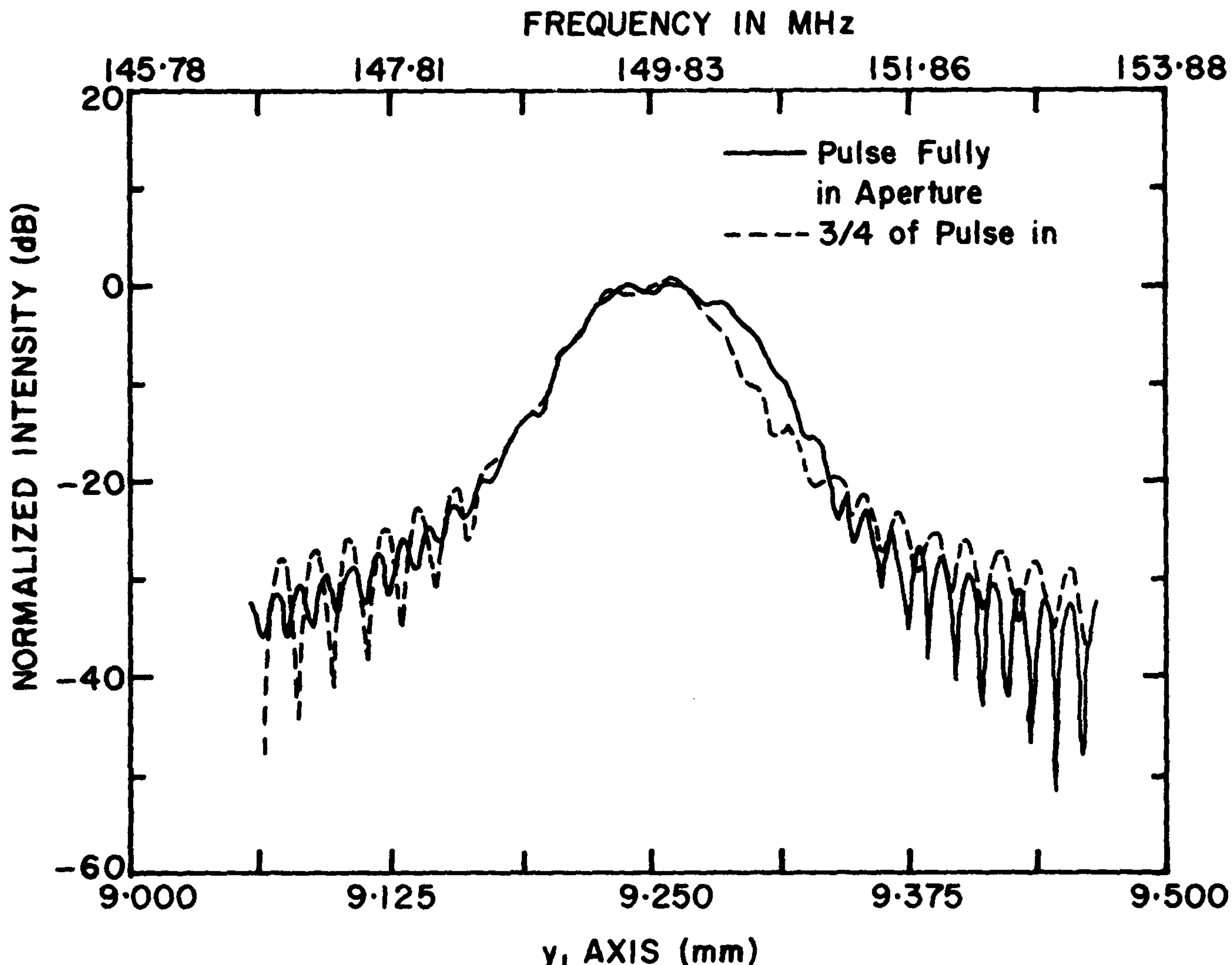

Figure 10 - LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE FOR A 5 μSEC PULSE MODULATED LINEAR FM AT TWO DIFFERENT INSTANTS OF TIME

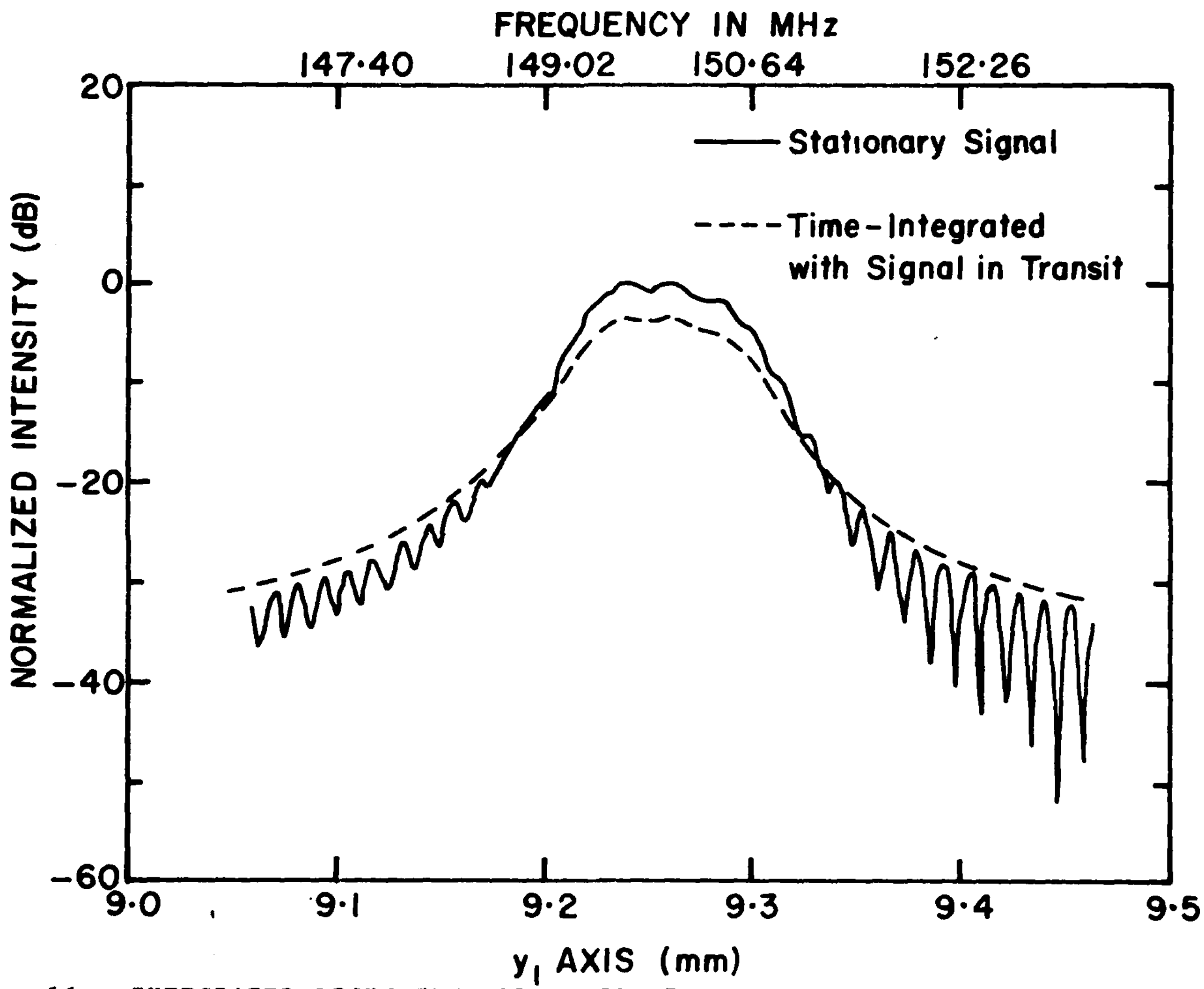

Figure 11 - INTEGRATED LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE FOR A 5 μSEC PULSE MODULATED LINEAR FM. (INTEGRATION TIME = 10 μSEC, F_0 =150 MHZ, Δf = 2 MHZ, α = 0.5 [illegible]/5 μSEC, T = 1, AND D = 20.5 mm)

interval of time, is also plotted for comparison. An enlarged plot showing the main lobe structures is given in Figure 12. As expected, there is a spread in frequency and smoothing of the side lobes for the time-integrated output due to the truncation of the signal by the finite aperture width. The experimental output power spectrum is also measured and shown in Figure 13. Some comparisons between the experimental and theoretical values are tabulated in Table II. The theoretical pow·r spectrum is graphically integrated with a cell width of 13 μm and again they agree reasonably well.

TABLE II

COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL INTEGRATED INTENSITY DISTRIBUTION FOR THE LINEAR FM SIGNAL

LINEAR FM PULSE WIDTH = 5 μSEC fo = 150 MHZ Δf = 2 MHZ	THEORETICAL INTENSITY	EXPERIMENTAL INTENSITY
CENTRE CELL (at 150 MHz, Normalized to Unity)	1	1
1st Cell on Right of Centre Cell	0.78	0.79
2nd	0.62	0.33
3rd	0.32	0.10
1st Cell on Left of Centre Cell	0.93	0.85
2nd	0.95	0.87
3rd	0.59	0.77
4th	0.29	0.43

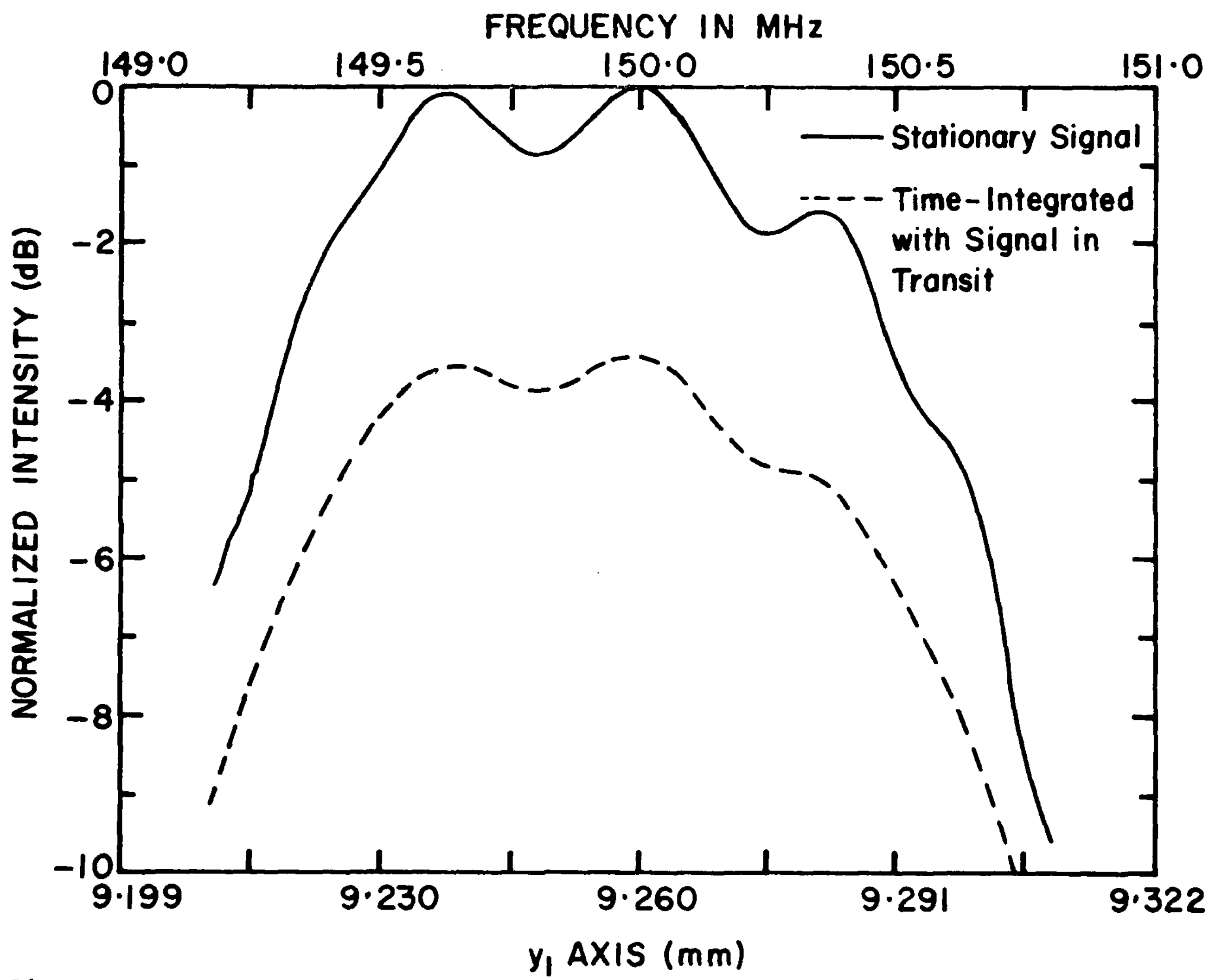

Figure 12 - ENLARGED, INTEGRATED LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE SHOWING THE MAIN LOBE STRUCTURE OF A 5 μSEC PULSE MODULATED LINEAR FM

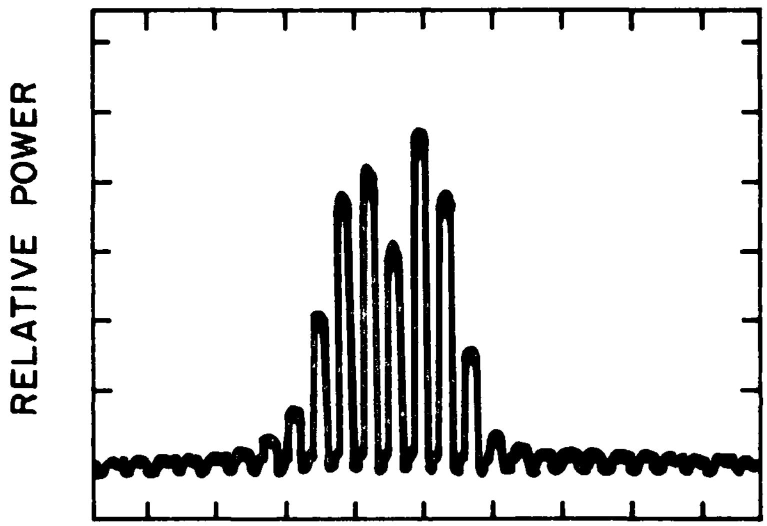

Figure 13 - INTEGRATED LIGHT INTENSITY DISTRIBUTION IN THE FREQUENCY PLANE OF A 5 μSEC PULSE MODULATED LINEAR FM DETECTED BY PHOTO DETECTOR ARRAY (CELL TO CELL CENTRE SPACING = 13 μm, INTEGRATION TIME = 50 μSEC)

6.0 CONCLUSIONS

In general, the experimental results agree well with theory for pulse modulated CW and linear FM signals. The effect on the integrated output due to the truncation of the signal by the finite aperture is to broaden the main lobe and smooth out the side lobes.

The theoretical and experimental results for linear FM signals show that there is considerable broadening of the spectra due to the fact that the frequency is modulated. The important point is that the power spectra of this type of signal is reproduced even though the spatial structure of the acoustic signal in the Bragg cell is now complex.

The combination of theoretical and experimental results available at this time indicate that the acousto-optic receiver can be used to give an accurate and instantaneous description of the power spectrum of several types of signals commonly encountered in ESM applications.

7.0 REFERENCES

1. R. Adler, "Interaction between Light and Sound", IEEE Spectrum, May 1967, pp. 42-54.

2. D.L. Hecht, "Multifrequency Acousto optic Diffraction", Trans. on Sonics and Ultrasonics, Vol. SU-24, No. 1, January 1977, pp. 7-18.

3. D.L. Hecht, "Spectrum Analysis Using Acousto-Optic Devices", Optical Engineering, Vol. 16, No. 5, Sept./Oct. 1977, pp. 461-466.

4. M. King, W.R. Benneth, L.B. Lambert and M. Arm, "Real-Time Electro-optical Signal Processors with Coherent Detection", Applied Optics, Vol. 6, No. 8, August 1967, pp. 1367-1375.

5. W.R. Klein and B.D. Cook, "Unified Approach to Ultrasonic Light Diffraction", IEEE Trans. on Sonics and Ultrasonics, July 1967, p. 123.

6. W.T. Maloney, "Acousto optical Approaches to Radar Signal Processing", IEEE Spectrum, October 1969, pp. 40-48.

APPENDIX A

COMPUTER PROGRAM LISTING

```
C       ' THIS PROGRAM IS WRITTEN TO CALCULATE THE INTENSITY DISTRIBUTION
C           IN THE FOCAL PLANE FOR DIFFERENT TYPES OF SIGNALS WITH GAUSSIAN
C           ILLUMINATION DISTRIBUTION AND ACOUSTIC LOSS '
C
C       F0 - CENTRE FREQUENCY OF SIGNAL
C       T1 - TOTAL TRANSIT TIME
C       ALAM - OPTICAL WAVELENGTH
C       F -    FOCAL LENGTH
C       D -    APERTURE WIDTH
C       ALFA - ACOUSTIC LOSS COEFFICIENT
C       TT - GAUSSIAN BEAM PROFILE CONSTANT
C       AK - LINEAR FM CHANGING RATE
C
C
        DIMENSION E1(222),E2(222),E3(222),Y1(222), Y2(222)
        DIMENSION Y3(222),Y4(222),Y5(222,50)
        E1(1)=221.; E2(1)=221.; E3(1)=221.; Y1(1)=221.
        Y4(1) =221.
        DO 21 MM= 1,2
        WRITE(2,11)
   11   FORMAT(/,       '  Y-POSITION(MM)        AMPLITUDE
     1        INTENSITY          NORMALIZED INTENSITY')
        F0=1.50E+6
        T1= 1.0E-5 *.5
        ALAM= 6.328E-7
        F=.4
        D=.041/2.
        VS=D/T1
        ALFA =1./T1 *.5
        C3= -ALFA*T1/D
        TT=1.
        C4= 2.* TT/D
        PI=3.14159
        AK= F0/T1*0.
        C5= AK/(2.*VS*VS)*2.*PI
        II=221
        DO 10 I=1,II
        Y=  F0*ALAM*F/VS
        YY= 1. -(1. /90.43  *((II-1) /2 -(I-1)))
        A =-D/2.
        B =D/2. -D/4.*3.*(MM-1)
        C1= 2.*PI*F0/VS
        C2= -C1*YY
        N=5
        TOL=0.
        KK=0
    2   CALL GAUQUS (A,B,P1,X,TOL,N,KK)
        KK=KK+1
        IF(KK.LE.0)  GO TO 3
        P1 = COS(( C1+C2)*X +C5*X*X) *EXP(C3*X-(C4*X)**2)
        GO TO 2
    3   RE=P1
    4   CALL GAUQUS (A,B,P2,X,TOL,N,KK)
        KK=KK+1
        IF(KK.LE.0)  GO TO 5
        P2=  SIN(( C1+C2)*X +C5*X*X) *EXP(C3*X-(C4*X)**2)
        GO TO 4
    5   AIM=P2
        AMP= SQRT(RE*RE +AIM*AIM) *1000. *EXP(-ALFA*T1/2.)
        AIN= AMP*AMP
        Y1(I+1) = YY*Y*1000.  +Y*1000.*99.
        Y4(I+1) = Y1(I+1)/1000. *( VS/(ALAM*F))
```

```
      Y2(I+1) =AIN
      Y3(I+1)=AMP
   10 CONTINUE
      DO 12 M=1,II
      IF(MM-2) 30,31,32
   30 E1(M+1) = Y2(M+1)/Y2((II+3)/2)
      A1=Y2((II+3)/2)
      E1(M+1) =10.* LOG10(E1(M+1))
   20 FORMAT(F12.5,F12.4,14X,2F20.4)
      GO TO 33
   31 E2(M+1) =10.*LOG10( Y2(M+1)/A1)
      GO TO 33
   32 E3(M+1) =10.*LOG10( Y2(M+1)/A1)
   33 AB=1.
   12 CONTINUE
   21 CONTINUE
      CALL INITT(120)
      CALL BINITT
      CALL CHECK(Y1,E1)
      CALL DSPLAY(Y1,E1)
      CALL CPLOT(Y1,E2)
      CALL INITT(120)
      CALL BINITT
      CALL CHECK(Y4,E1)
      CALL DSPLAY(Y4,E1)
      CALL CPLOT(Y4,E2)
      CALL FINITT(0,700)
      STOP
      END
      SUBROUTINE GAUQUS(DD,BB,FX,X,TOL,NM,K)
      DIMENSION AB(30), AC(30), AD(4), A(8,8)
      EQUIVALENCE(A(1,1),AB(1)), (A(7,4),AC(1)),(A(5,8
     1),AD(1))
      DATA AB/2., .2011941, .3941514, .5700782,
     1 .7244177, .8482066, .9378734, .[illegible],
     1 .5555556, .[illegible], .2304583, .[illegible]
     1,.6423493, .8015781, .9175984, .9841831,
     1 .2369269, .4786287, .5688889, .[illegible],
     1 .5190961, .730152, .8870626, .9782287,
     1 .129485, .2797054, .3818301, .4179592,
     1 .3242534, .6133714/
      DATA AC/ .8360311, .9681602, .8127438E-1,
     1 .1806482, .2606107, .3123471, .3302394,
     1 .4058452, .7415312, .9491079, .5566857E-1
     1, .1255804, .1862902, .2331938, .2628045,
     1 .2729251, .5384693, .9061799, .4048401E-1,
     1 .0921215, .1388735, .178146, .2078161,
     1 .2262832, .2325516, .7745967, .3075324E-1,
     1 .7036605E-1, .1071592, .1395707/
      DATA AD/ .[illegible], .186161, .1984315, .[illegible]/
      IF(TOL.LE.0.) TOL=1.E-4
      K=K+1
      IF(K-4) 400,303,601
  400 IF(K-2) 601,301,302
  601 SUM=0.0
      IND=0
      D=DD
      B=BB
      N=(NM+1)/2
  600 CALC1 =.9999999E74
      IT=0
   12 SCL1 =(B-D)/2.
      SCL2 =(B+D)/2.
```

```
   13 X=SCL2
      K=2
      RETURN
  303 F0=FX
      J=N
   21 CALC2=0.
      I=1
      M=9-J
      IF(I.EQ.J )  GO TO 3
   22 L=9-I
      X=A(L,M) *SCL1+SCL2
      K=0
      RETURN
  301 TEMP =FX
      X=(-A(L,M) ) *SCL1+SCL2
      K=1
      RETURN
  302 CALC2=CALC2 +A(I,J)*(TEMP+FX)
      I=I+1
       IF(I.LT.J) GO TO 22
    3 CALC2=CALC2 + A(I,I) *F0
      CALC2 =CALC2*SCL1
      IF(IT.NE.0)  GO TO 8
    7 IF(ABS(CALC1).GT.1.)  GO TO 1111
      IF(ABS(CALC1-CALC2) .LT.TOL)  GO TO 5
      GO TO 6
 1111 IF(ABS((CALC1-CALC2)/CALC1) .LT. TOL) GO TO 5
    6 CALC1=CALC2
      J=J+1
      IF(J-8) 21,21,11
    8 FHALF=FHALF +CALC2
       IF(IT.NE.1)  GO TO 15
      SAVE=FHALF
      SCL1=(PREND-B)/2.
      SCL2=(PREND+B)/2.
      IT=2
      GO TO 13
   15 IF(ABS((FHALF-CALC1)/RERR).LT.TOL) GO TO 16
      CALC1 =SAVE
      GO TO 110
   16 SUM= SUM+FHALF
      IF (PREND.GE.RHEND) GO TO 114
      D=PREND
      B=RHEND
      IND=1
      N=8
      FHALF =0.0
     GO TO 600
  114 CALC2 =SUM
    5 FX=CALC2
      K=-1
      RETURN
   11 IF(IND.GT.0) GO TO 110
      RERR =CALC2
      RHEND =B
      N=8
  110 PREND =B
      B=(B+D) /2.
      IT=1
      FHALF=0.0
      GO TO 12
      END
```

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